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APPLICATION FOR UNITED STATES LETTERS PATENT

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FOR:	ACTIVE MATRIX LIQUID CRYSTAL DISPLAY DEVICE AND MANUFACTURING METHOD THEREOF
DOCKET NO.:	157330/99

Active Matrix Liquid Crystal Display Device and Manufacturing Method thereof

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an active matrix liquid crystal display device and a manufacturing method thereof. The present invention particularly relates to an active matrix liquid crystal display device having a color filter on a substrate on which switching elements are formed and a manufacturing method thereof.

2. Description of the Related Art

In recent years, the development of an active matrix liquid crystal display device (AMLCD) using thin film transistors (TFT) is actively developed. An on-chip color filter structure is reported in the Japanese Patent Application Laid-open No. Hei-8-122824 (to be referred to as "Prior Art 1" hereinafter), 9-292633 (to be referred to as "Prior Art 2" hereinafter) and so on. In the structure, a color filter is fabricated on a substrate on which TFTs are formed (to be referred to as "TFT substrate" hereinafter). It enables to minimize the discrepancy of the position of the color filter to the TFT substrate.

FIGS. 1(a) and 1(b) show the unit pixel area of an AMLCD to which the on-chip color filter structure disclosed by Prior Art 1 is adopted. FIG. 1(a) is a plan view and FIG. 1(b) is a cross-sectional view taken along line A-A' of FIG. 1(a).

A TFT substrate 21 consists of a glass substrate 9, scanning lines 1 formed on the glass substrate 9, for selecting a pixel to which a signal is written, signal lines 2 for supplying a signal voltage and TFTs 3 each for driving a pixel formed at the intersection between a scanning line and a signal line. Among these constituent elements, each TFT 3 is comprised of a gate electrode 12 provided on the glass substrate 9, a gate insulating layer 10 provided to cover the gate electrode 12, a semiconductor layer 24 formed on the gate insulating layer 10, a drain electrode 13, a source electrode 14 and a passivation film 11 provided to cover all the above-stated constituent elements. The scanning line 1 is connected to the gate electrode 12, and the signal line 2 is connected to the drain electrode 13. A color filter 8 and a black matrix 4 are provided on the passivation film 11 and an overcoat layer 19 is further formed to protect the color filter 8 and the black matrix 4. The color filter 8 is formed by coating a pigment dispersion type photosensitive negative resist by spin coating and exposing, developing and sintering the resist. A pixel electrode 7 is provided on the overcoat layer 19 and connected through a contact hole 5 to the source electrode 14 of the TFT. Also, an alignment layer (not shown) for controlling liquid crystal molecules to have an arrangement and an inclination (pre-tilt) suited to the operation mode of liquid crystal is provided on the overcoat layer 19 and the pixel electrode 7.

A color filter (CF) substrate 22 has a counter electrode 16 and an alignment layer (not shown) provided on a color filter (CF) glass substrate 15. Further, the TFT substrate 21, the CF substrate 22 and a liquid crystal layer 17 put between the TFT substrates 21 and the CF substrate 22 form a liquid crystal element as a whole. With such an on-chip color filter structure, the color filter and the black matrix are formed on the TFT substrate, thereby making it possible to advantageously reduce the alignment errors of the color filter and the black matrix with respect to pixels caused by misregistration between the TFT substrate 21 and the CF substrate 22.

Here, if the film thickness of the color filter is set at 1.2μm, that of the gate electrode is set at 0.2 μm, that of the semiconductor layer is set at 0.3 μm, that of the drain electrode is set at 0.2 μm and that of the passivation film is set at 0.3 μm, then the film thickness of the color filter on a contact hole portion is 1.0 μm.

Nevertheless, the negative resist used as a color filter is colored and normally low in sensitivity. Due to this, large exposure is required if the color filter is as thick as 1.0 μm, resulting in the problems that it is difficult to make a device small in size and that productivity is low. Besides, due to the large exposure, residue tends to disadvantageously occur onto the lower elements, i.e., the passivation film and the source electrode after development. Further, while pigments are

employed by being dispersed into an acrylic resin, if the sensitivity of this acrylic resin increases, the pigments are hardened only in the vicinity of the surface of the color filter (in a region from 0.3 to 0.5 μm from the surface of the color filter) due to photo-crosslinkage and the shape of the neighborhood of the color filter and that of the contact hole portion are undercut after development. This causes the problems that contact resistance between the pixel electrode and the source electrode increases, adhesion between the color filter and the substrate deteriorates, and the like. That is, in case of the LCD with the on-chip color filter structure according to Prior Art 1, the color filter is thick on the contact hole portion and the neighborhood of the pixels and the photo-crosslinkage of the color filter, therefore, occurs to the surface of the color filter. As a result, this device has disadvantages in that it is difficult to make the device small in size and to improve a aperture ratio as well as productivity is low.

Moreover, with the on-chip color filter structure, in the pigment dispersion type photosensitive negative resist serving as a color filter, a photosensitive acrylic material sensitive to i-rays, g-rays and h-rays is employed as a base resin. As can be seen from the relationship between the film thickness of this high photosensitive color filter resist (e.g., CM-7000 manufactured by Fujifilm Olin Co., Ltd.) and photo-crosslinkability (shown in FIG.

2), the color resist is low in transmittance with respect to i-rays and photo-crosslinkable property suddenly decreases at around 0.3 to 0.5 μm from the surface since the color resist is colored. Normally, the film thickness of the color filter is 0.3 to 0.5 μm. However, if development time is long or over-development occurs for the above-stated reasons, the color filter is isotropically dissolved on the bottom thereof having low photo-crosslinkability and the filter disadvantageously becomes an inverse tapered shape.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an on-chip color filter structure capable of making a device small in size and enhancing an aperture ratio. According to the present invention, a color filter is applied to an on-chip color filter structure by removing a gate insulating layer and a passivation film on a pixel opening portion. Due to this, the color filter on a stepped portion such as the source electrode of a TFT becomes thinner than the color filter on the pixel opening portion and development can be carried out with small exposure. Thus, means for making a device small in size and enhancing an aperture ratio is provided.

According to the first invention, there is provided an AMLCD having a first substrate and a second substrate, at least one of the first and second substrates being

transparent; a liquid crystal layer put between the first and second substrates; and a color filter, the first substrate including a plurality of scanning lines, a plurality of signal lines crossing the scanning lines in a matrix manner, a plurality of TFTs formed at intersections of the scanning lines and signal lines, respectively, and pixel electrodes connected to each of the TFTs, the second substrate including a counter electrode, liquid crystal molecules being driven by an electric field between the pixel electrode and the counter electrode to thereby make display, characterized in that the color filter is formed on a passivation film for protecting each of the TFTs; the pixel electrode is arranged on the color filter and connected to the TFTs through a contact hole provided in the passivation film and the color filter; and a gate insulating layer and the passivation film of each of the TFTs are removed in a light transmission region within pixels surrounded by the scanning lines and the signal lines.

According to the second invention, there is provided an AMLCD having a first substrate and a second substrate, at least one of the first and second substrate being transparent; a liquid crystal layer put between the first and second substrate; a color filter; and an overcoat layer protecting the color filter, the first substrate including a plurality of scanning lines, a plurality of signal lines crossing the plurality of scanning lines in a matrix manner,

a plurality of TFTs formed at intersections of the scanning lines and the signal lines, respectively, pixel electrodes connected to each of the TFTs, the second substrate including a counter electrode, liquid crystal molecules being driven by an electric field between the pixel electrode and the counter electrode to thereby make display, characterized in that the color filter is formed on a passivation film for protecting each of the TFTs; the overcoat layer is formed on the color filter; the pixel electrode is arranged on the overcoat layer and connected to the TFTs through a contact hole provided in the passivation film, the color filter and the overcoat layer; and a gate insulating layer and the passivation film of each of the TFTs are removed in a light transmission region within pixels surrounded by the scanning lines and the signal lines.

The LCD according to the first or second invention is characterized in that the color filter on the contact hole portion is thinner than the color filter in the light transmission region.

With the on-chip color filter structure of the present invention, the gate insulating layer and the passivation film on a pixel opening portion for forming a color filter are removed, whereby the thickness of the color filter on a stepped portion, such as a source electrode, on which portion the thin film transistor is formed is set smaller than that of the color filter on the

opening portion using the flattening property of the color resist. Specifically, if the film thickness of the color filter on the opening portion is 1.2 μm, a total of the thicknesses of the entire films on a stepped portion of the thin film transistor is 1.2 μm, as well, and the thickness of the constituent elements other than the color filter becomes almost 1.0 μm. Thus, the film thickness of the color filter on the stepped portion becomes 0.2 μm. This thickness is sufficient to cause photo-crosslinkage, so that a fine pattern can be formed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1(a) and 1(b) show one example of a conventional LCD, wherein FIG. 1(a) is a schematic plan view thereof and FIG. 1(b) is a cross-sectional view of the unit pixel part thereof;

FIG. 2 shows the relationship between the thickness of a color filter (CF) and photo-crosslinkability;

FIGS. 3(a) and 3(b) show a LCD in Embodiment 1 according to the present invention, wherein FIG. 3(a) is a plan view thereof and FIG. 3(b) is a cross-sectional view thereof;

FIGS. 4(a) to (d) shows a method of manufacturing the LCD in Embodiment 1 according to the present invention;

FIGS. 5(a) and 5(b) show a LCD in Embodiment 2 according to the present invention, wherein FIG. 5(a) is a plan view thereof and FIG. 5(b) is a cross-sectional view thereof; and

FIGS. 6(a) to (e) shows a method of manufacturing the LCD in Embodiment 2 according to the present invention.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

The preferred embodiments of the present invention will be described hereinafter with reference to the accompanying drawings.

(Embodiment 1)

FIGS. 3(a) and 3(b) show the unit pixel part of a LCD having an on-chip color filter structure in this embodiment. Specifically, FIG. 3(a) is a plan view thereof and FIG. 3(b) is a cross-sectional view thereof taken along line A-A′ of FIG. 3(a). As shown in FIG. 3(a), a TFT substrate 21 has, on a glass substrate 9, scanning lines 1 each for selecting a pixel to which a signal is written, signal lines 2 each for supplying a to-be-written signal, and TFTs 3 each provided at the intersection between a scanning line and a signal line, for driving a pixel. As shown in FIG. 3(b), each TFT 3 is comprised of a gate electrode 12 provided on the glass substrate 9, a gate insulating layer 10 provided to cover the gate electrode 12, a semiconductor layer 24 formed on the gate insulating layer 10, a drain electrode 13, a source electrode 14 and a passivation film 11 provided to cover the above-stated constituent elements. The scanning line 1 is connected to the gate electrode 12 and the signal line 2 is connected to the drain electrode 13. The passivation film 11 and the gate insulating layer

10 on a pixel opening portion 6 are removed. A color filter 8 and a black matrix 4 are provided on the passivation film 11. A pixel electrode 7 is connected to the source electrode 14 of the TFT 3 through a contact hole 5 provided in the pixel electrode 7. Also, an alignment layer (not shown) for controlling liquid crystal molecules to have an arrangement and an inclination (pre-tilt) suited to the operation mode of liquid crystal is provided on the pixel electrode 7. The film thickness of the gate electrode is set at 0.2 μm, that of the gate insulating layer is set at 0.5 μm, that of the semiconductor layer is set at 0.3 μm, that of the drain electrode is set at 0.2 μm and that of the passivation film is set at 0.3 μm. The thickness of the color filter on the pixel opening portion is set at 1.2 μm so as to secure a sufficient chromaticity range. A counter substrate 22 has a counter electrode 16 and an alignment layer (not shown) provided on a counter glass substrate 15. The TFT substrate 21, the counter substrate 22 and a liquid crystal layer 17 put between the TFT substrates 21 and the counter substrate 22 form one liquid crystal element as a whole. Here, a pigment dispersion type high photosensitive negative resist (such as CM-7000 manufactured by Fujifilm Olin Co., Ltd.) is formed by spin coating. Due to this, even if the lower constituent elements have differences in level, they can be coated with a film having a flat surface. When the negative resist is coated so that the film thickness of the

color filter on the pixel opening portion becomes 1.2 μm, the thickness of the color filter on a contact hole formation portion is 0.2 μm and the total thickness on the contact hole formation portion can be reduced by 0.8 μm from that of the conventional thickness since the gate insulating layer has a width of 0.5 μm and the passivation film has a width of 0.3 μm. This makes it possible to set the thickness of the color filter at not more than 0.3 μm with which photo-crosslinkage sufficiently occurs. Thus, it is possible to sufficiently expose the color filter and to realize fine patterning. As a result, the contact hole can be formed in a fine pattern having a diameter of 5 μm.

FIG. 4 is an explanatory view for a method of manufacturing an LCD having the on-chip color filter structure in this embodiment.

First, as shown in FIG. 4(a), 0.2 μm of metal such as Cr is formed on the glass substrate 9 and patterned to thereby form a scanning line (not shown) and a gate electrode 12. Next, 0.5 μm of a gate insulating layer 10 and 0.3 μm of a semiconductor layer 24 are formed by the plasma CVD method and the semiconductor layer 24 of the TFT is patterned to have a island structure. Further, 0.2 μm of metal such as Cr is formed and patterned to thereby form a signal line (not shown), a drain electrode 13 and a source electrode 14. Further, 0.3 μm of silicon nitride SiN is formed, as a passivation film 11, by the plasma CVD method. Then, the passivation film 11 and gate insulating

layer 10 on a contact hole portion 5 and on a pixel opening portion 6 are removed by dry etching.

Thereafter, as shown in FIG. 4(b), a photosensitive black resist (e.g., CK-S-171 manufactured by Fujifilm Olin Co., Ltd.) into which pigments, titanium oxide and the like are dispersed, is coated and patterned, thereby forming a black matrix 4 by 1 μm on a TFT light shielding portion and a light leakage region.

Next, as shown in FIG. 4(c), an RGB pigment dispersion type resist (e.g., CM-7000 manufactured by Fujifilm Olin Co., Ltd.) is spin-coated and then exposed, developed and sintered to thereby form a color filter 8. In this case, R, G and B pigments are coated by 1.2 μm, respectively. Since spin coating method is used to coat the resist, the color filter 8 coats the lower layers to provide a flat surface even if they have differences in level. Due to this, the thickness of the color filter on the contact hole portion and that of the outline of the color filter pattern become 0.2 μm as stated above. An i-ray stepper is used in exposure to allow the formation of a fine pattern. Since a high photosensitive color resist is used and the film thickness of a pattern formation part is small, it is possible to form the pattern of a contact hole of 5 μm × 5 μm with exposure as small as about 100 mJ and to provide an ordinary tapered cross section as desired. Then, development is performed with a 0.12% TMAH (tetramethylammonium (hydro) oxide) solution for 60 to 100

seconds and sintering is performed at 220°C for one hour.

Finally, as shown in FIG. 4(d), 0.5 μm of indium-tin oxide (ITO) serving as a transparent electrode is formed and patterned to thereby form a pixel electrode 7. After an alignment layer is coated and a rubbing treatment is conducted, the electrode 7 is joined to a counter electrode through a predetermined gap. Liquid crystal is injected into the gap. Thus, an AMLCD is completed.

According to this embodiment, the gate insulating layer and the passivation film on the pixel opening portion are removed, whereby it is possible to make the color filter on the contact portion and on the pattern outline portion thin while maintaining the color filter on the pixel opening portion to be thick, to use a high photosensitive color resist and to form a fine pattern with small exposure. As a result, it is possible to manufacture an LCD having good display quality, high precision and a high aperture ratio.

(Embodiment 2)

FIG. 5(a) and (b) show the unit element part of a LCD having an on-chip color filter structure in this embodiment. Specifically, FIG. 5(a) is a plan view thereof and FIG. 5(b) is a cross-sectional view thereof taken along line A-A' of FIG. 5(a). A TFT substrate 21 has, on a glass substrate 9, scanning lines 1 each for selecting a pixel to which a signal is written, signal lines 2 each for

supplying a to-be-written signal and TFTs 3 each for driving a pixel at the intersection of a scanning line and a signal line. Each TFT 3 is comprised of a gate electrode 12 provided on the glass substrate 9, a gate insulating layer 10 provided to cover the gate electrode 12, a semiconductor layer 24 formed on the gate insulating layer 10, a drain electrode 13, a source electrode 4 and a passivation film 11 provided to cover the above-stated constituent elements. The scanning line 1 is connected to the gate electrode 12 and the signal line 2 is connected to the drain electrode 13. The passivation film 11 and the gate insulating layer 10 on a pixel opening portion 6 are removed. A color filter 8 and a black matrix 4 are provided on the passivation film 11 and a transparent overcoat layer 19 is provided to protect them. Also, a pixel electrode 7 is connected to the source electrode 14 of the TFT 3 through a contact hole 5 provided in the pixel electrode 7. An alignment layer (not shown) for controlling liquid crystal molecules to have an arrangement and an inclination (pre-tilt) suited to the operation mode of liquid crystal is provided on the pixel electrode 7. The film thickness of the gate electrode is set at 0.2 μm, that of the gate insulating layer is set at 0.5 μm, that of the semiconductor layer is set at 0.3 μm, that of the drain electrode is set at 0.2 μm and that of the passivation film is set at 0.3 μm. The thickness of the color filter on the pixel opening portion is set at 1.2 μm so as to secure a

sufficient chromaticity range. Further, the film thickness of the overcoat layer 19 is set at 0.3 μm. A counter substrate 22 has a counter electrode 16 and an alignment layer (not shown) provided on a counter glass substrate 15. The TFT substrate 21, the counter substrate 22 and a liquid crystal layer 17 put between the TFT substrates 21 and the counter substrate 22 form one liquid crystal element as a whole. Here, the diameter of a contact hole in each of the color filter 8 and the overcoat layer 19 is set at 5 μm × 5 μm.

FIG. 6 is an explanatory view for a method of manufacturing a LCD having the on-chip color filter structure in this embodiment. The steps of first forming the scanning line 1, the signal line 2, the TFT 3 and the black matrix 4 on the glass substrate 9 are the same as those in Embodiment 1 (FIG. 6(a)). Next, an RGB pigment dispersion type resist (e.g., CM-7000 manufactured by Fujifilm Olin Co., Ltd.) is spin-coated, exposed, developed and sintered to thereby pattern only a pixel pattern outline portion (FIG. 6(b)). Here, R, G and B pigments are coated by 1.2 μm, respectively. Since the resist is coated by spin coating, the color filter is flattened sufficiently and coats the lower layers to flatten differences in level. Due to this, as described above, the film thickness of the pattern outline portion becomes 0.4 μm. Next, a positive photosensitive acrylic resin (e.g., PC-403 manufactured by JSR) as the overcoat layer 19 is subjected to coating,

exposure, development and sintering, and a contact hole if formed (FIG. 6(c)). Next, using the overcoat layer 19 as a mask, dry etching is performed with CF4/O2 gas and the pattern of the contact hole 5 is formed on the color resist. Since the thickness of the color resist on the contact portion is as small as 0.4 μm, dry etching processing time is short and the surface of the overcoat layer is not damaged (FIG. 6(d)). Finally, 0.05 μm of ITO serving as a transparent electrode is formed and patterned to thereby form a pixel electrode 7 (FIG. 6(e)). After an alignment layer (not shown) is coated and a rubbing treatment is conducted, the electrode 7 is joined to a counter electrode through a predetermined gap. Liquid crystal is injected into this gap. Thus, an AMLCD is completed.

This embodiment is characterized by providing an overcoat layer on a color filter to protect the color filter in the LCD having the color filter formed on the TFT substrate. This embodiment is also characterized in that the thickness of the color filter on the contact portion can be made thinner by removing the gate insulating layer and the passivation film on the pixel opening portion and in that a contact hole is formed by dry etching with the overcoat layer used as a mask without damaging the surface of the overcoat layer. With this characteristic constitution, it is possible to form a LCD with higher precision, a higher aperture ratio and better display quality than that in Embodiment 1.

The present invention has advantages in that, in a LCD of an on-chip color filter structure having a color filter provided on a TFT substrate, the thickness of the color filter on the contact hole portion can be made thinner while maintaining the thickness of the color filter in the pixel opening region by removing the gate insulating layer and the passivation film in the pixel opening region and a contact hole of a fine and good shape can be formed by development or dry etching. Besides, the present invention has an advantage of providing a LCD with high precision and a high aperture ratio since the device can be further made smaller in size.